5.11 ELECTROMAGNETIC CALORIMETER (ECAL)

The Electromagnetic Calorimeter (ECAL) of the AMS-02 experiment is a fine grained lead-scintillating fiber sampling calorimeter that allows precise, 3-dimensional imaging of the longitudinal and lateral shower development, providing high ($\geq 10^6$) electron/hadron discrimination (identify particle type) in combination with the other AMS-02 detectors and good energy resolution (energy measurement). The calorimeter also provides a stand-alone photon trigger capability to AMS. The ECAL measures the energy of electrons, positrons and gamma rays up to 1 TeV.

The active sensing element of the ECAL consists of layers of lead foils and polymer scintillating fibers (Figure 5.11-1). Each lead foil a lead-antimony alloy with a density of 11.2 ± 0.5 gr/cm^{3}with an effective thickness of 0.04 inch (1 mm). Each lead layer is grooved (rolled) on both sides (Figure 5.11-2) to accommodate the PolyHiTech Polifi 0244-100 scintillating fibers. Each fiber is 1.0 mm in diameter and is secured in the aligned groves with BICRON BC-600 Optical glue that is applied as lead layers are assembled and pressed together. Each layer consists of 490 fibers across the 25.9 inch (658 mm) width of the layers Lead layers are grouped together in "superlayers" (Figure 5.11-3) that are comprised of eleven layers of lead foil and ten layers of scintillating fibers. Each superlayer has all scintillating fibers oriented in the same direction, alternating the direction orthogonally of the fibers with each of the superlayers (Figure 5.11.1), 9 in total. Once assembled and pressed, each cured superlayer is milled to a uniform thickness of 0.7 inch (18.5 mm) thick. The superlayers are assembled as larger elements and sized (milled) for flight into squares with 25.9-inch (658 mm) long sides. The last (bottom) lead layer of the bottom superlayer has been replaced with a milled aluminum plate to reduce weight of the overall ECAL. Estimated savings by replacing the last plate with aluminum is approximately 2 kg.

Figure 5.11-1 Three Superlayers Showing Alternating Layers Of Lead Foil And Scintillating Fibers And Alternating Superlayer Orientation

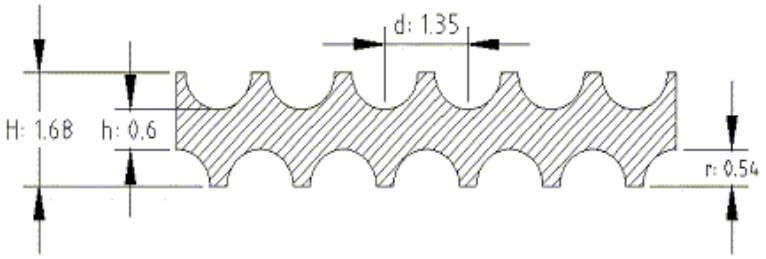

Figure 5.11-2 Individual Lead Foil Profile (Dimensions in mm)

The ”pancake” of lead layers with scintillating fibers is the foundation of the ECAL sensor. Sensitive photomultiplier tubes (PMTs) are positioned around the periphery of the brick to sense photons generated by the passage of particles, secured against the edges of the brick where the Superlayer fibers terminate. A position of one of these PMT locations with its four pixels is depicted in red in figure 5.11-3. A side view of the ECAL (before the PMTs are installed) is provided in Figure 5.11.4.

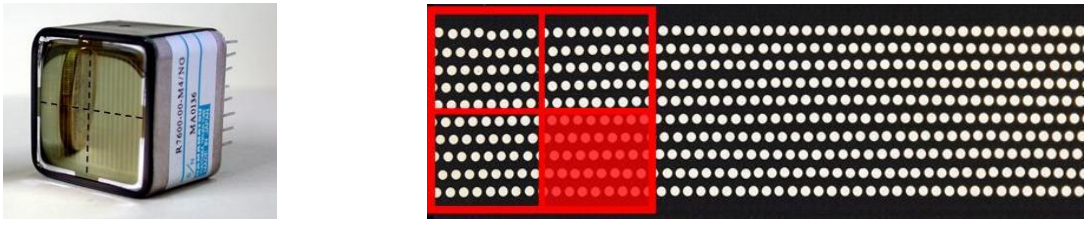

Figure 5.11-3 The 4-Anodes Photomultiplier (left) and the area it covers on a

Superlayer (right)

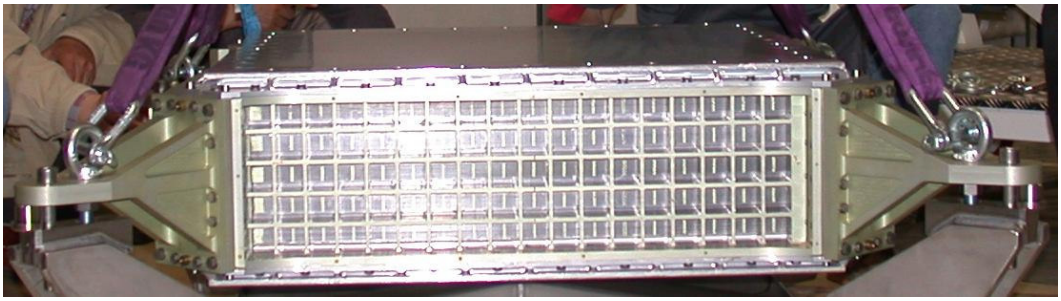

Figure 5.11-4 View of the ECAL showing the Side Panel grid prior to the installation of the PMTs

The ECAL is approximately 31.5 inches (800 mm) square x 9.8 inches (250 mm) high and weighs approximately 1478 lbs (643 Kg). Approximately 75% of this weight is due to the lead foils.

The ECAL "pancake" is supported by the ECAL "box". The box is made of 6 elements (Figure 5.11-5). The top and bottom pieces are aluminum honeycomb plates framed with aluminum. The plates are bolted to four lateral panels along the edges. The four lateral panels are made of Aluminum plates, 4 inch (10.16 cm) thick, carved with squared holes of 1.26-inch (32 mm) sides to house the light collection system. Four corner brackets, made of Aluminum plate, link the four plates together and connect the detector to the USS-02 at the bottom of the AMS-02 instrument (Figure 5.11-6). The four mounting locations include a pair of radially slotted holes so that the loads of the ECAL are transferred to the USS-02, but the loads from the USS-02 that are transferred into the ECAL are limited.

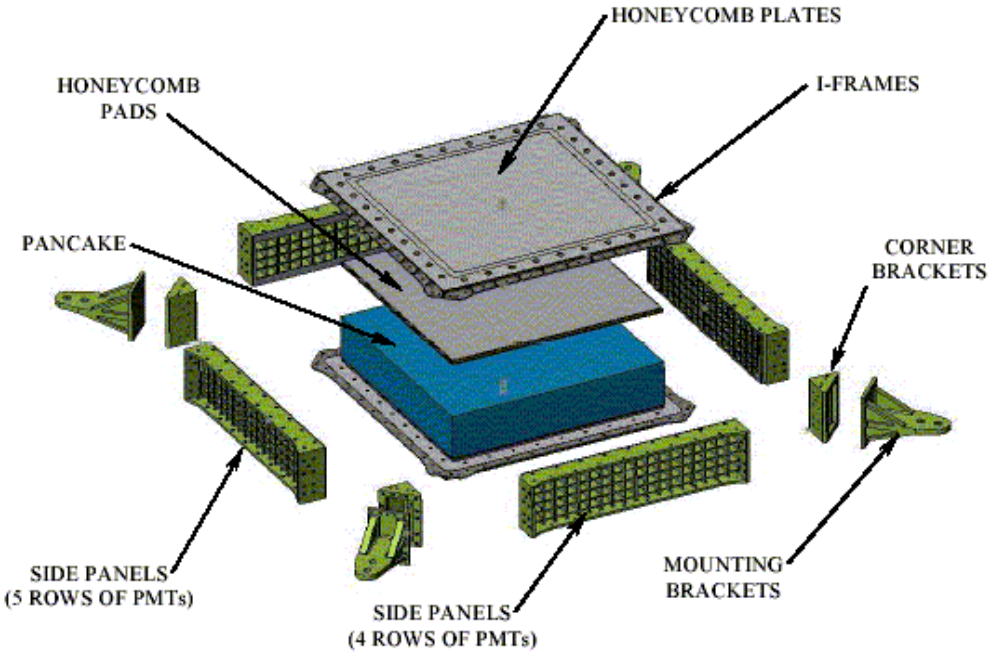

Figure 5.11-5 ECAL Construction

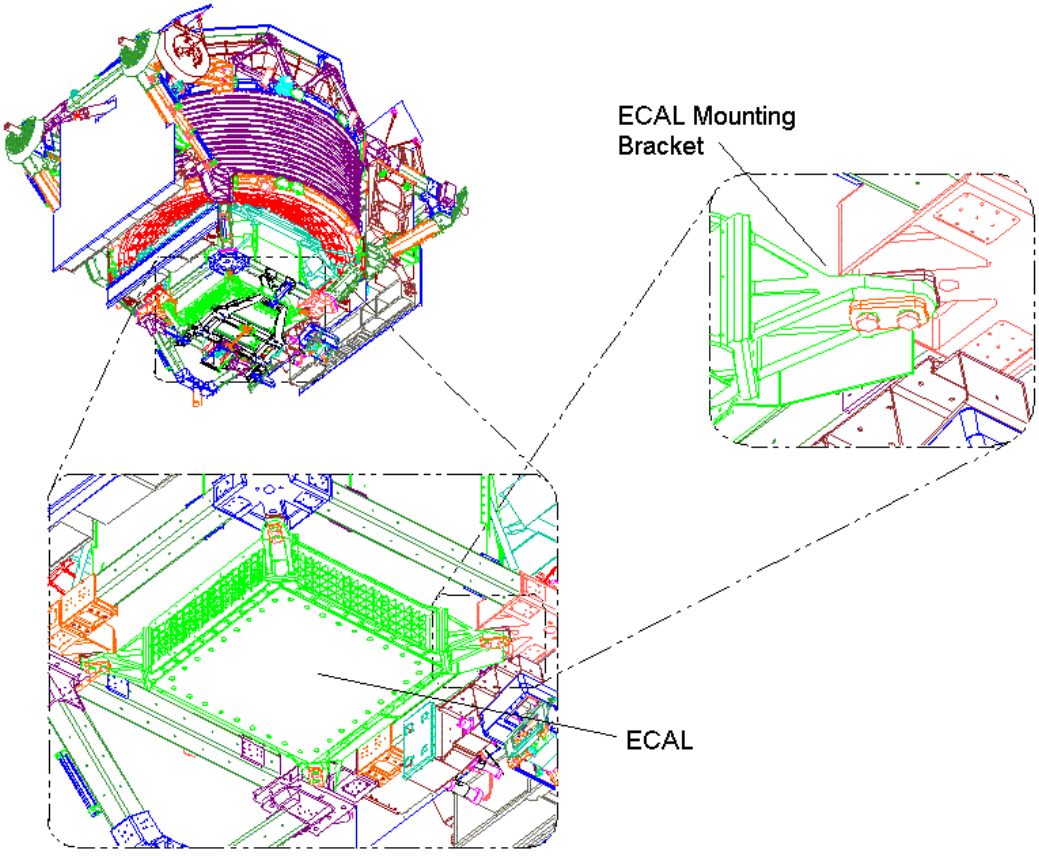

Figure 5.11-6 Location of the ECAL on the AMS-02

The light collection system is mounted about the periphery of the ECAL pancake in the four lateral panels. Two sides, serving 4 superlayers, have 72 holes while the two other faces, serving 5 superlayers, have 90 holes each (Figure 5.11-7).

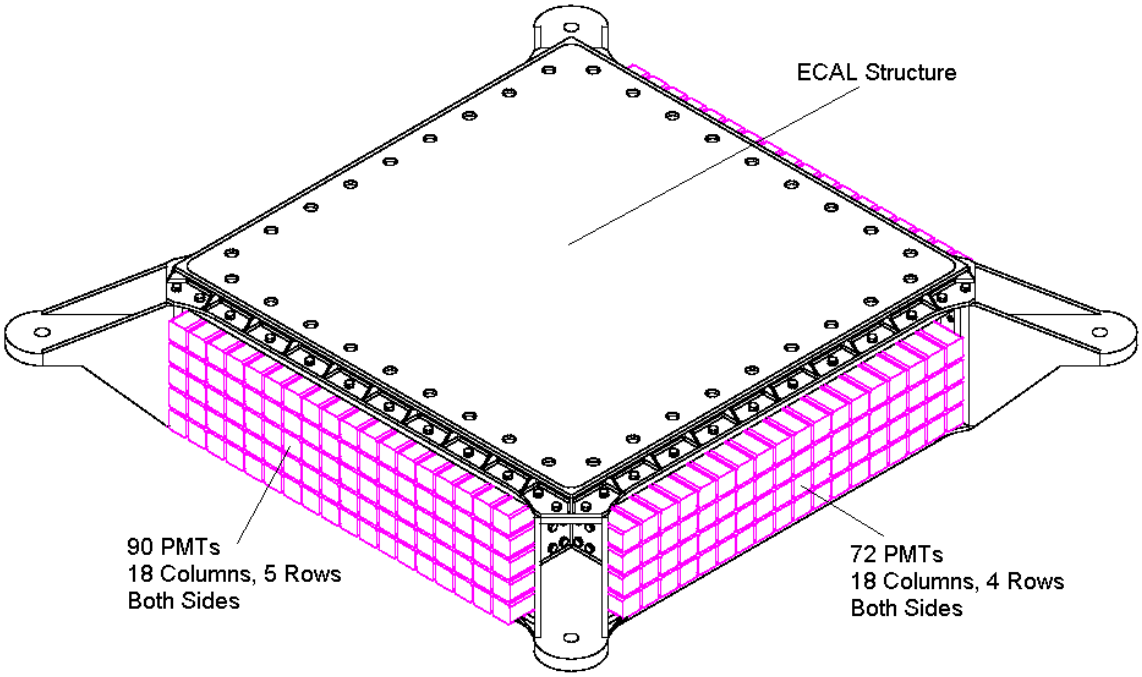

Figure 5.11.7 ECAL Assembly showing the location of the 324 PMTs

For each hole, the light collection consists of a mu-metal square tube for magnetic field shielding, light guides and Photomultiplier Tubes (PMTs) with driver electronics (Figure 5.11-8). An Aluminum backplate is fixed on the rear side of each lateral panel to keep all the light collection systems in the correct position, securely engaged with the lead foil surface and scintillating fibers, and to prevent any displacements of the systems themselves. The glass front of the ECAL PMT is covered with a DC 93-500 Optical coupling pad and is potted in the same material, encapsulating the glass element. The ECAL Intermediate Boards (EIBs) (Figure 5.11-9) are electronic boards coated and fixed in aluminum frames directly mounted on the ECAL back panels. The EIBs provide the interface for the PMTs to get commands from the data acquisition system and to send data from driver electronics to it.

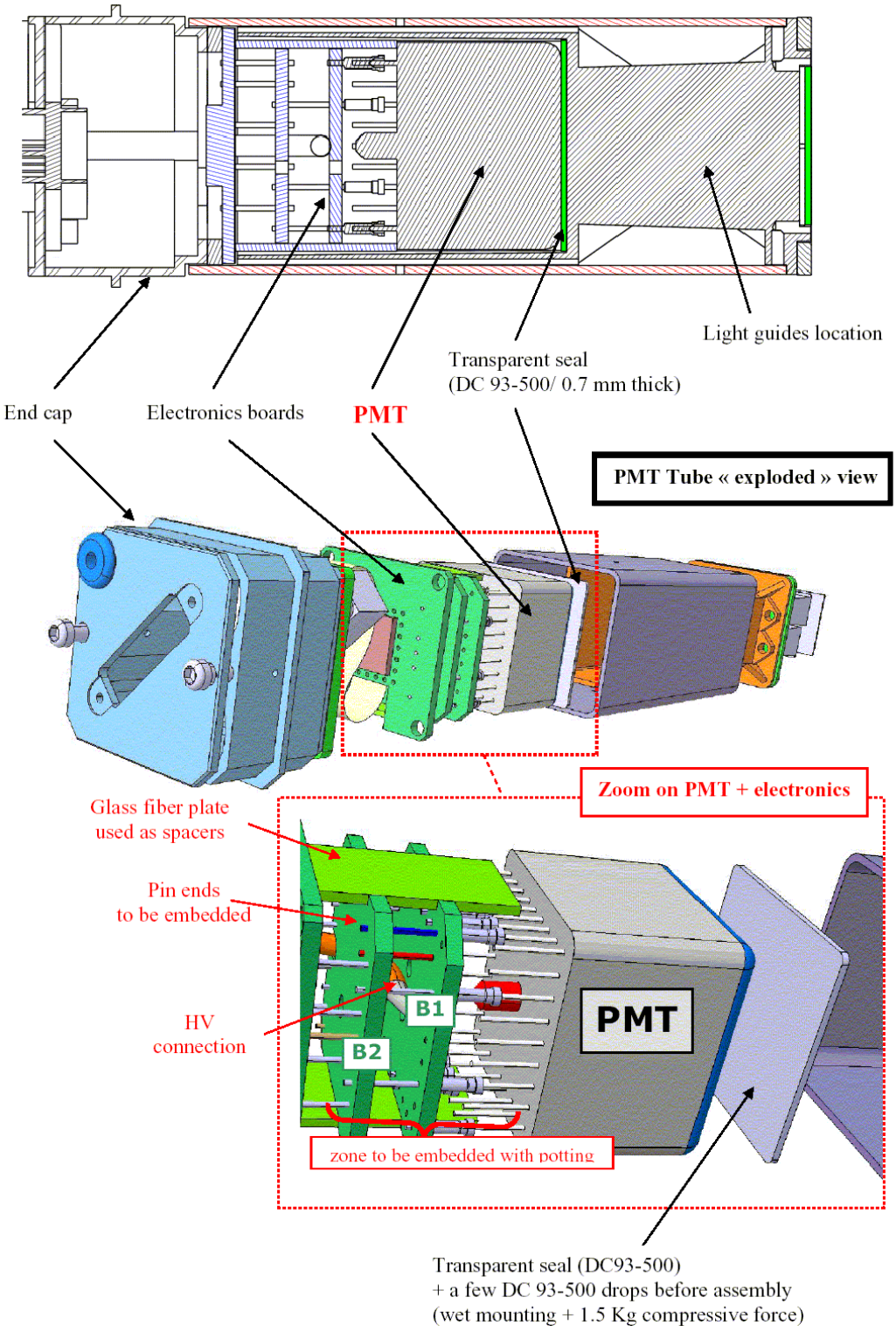

Figure 5.11-8 ECAL PMT Construction

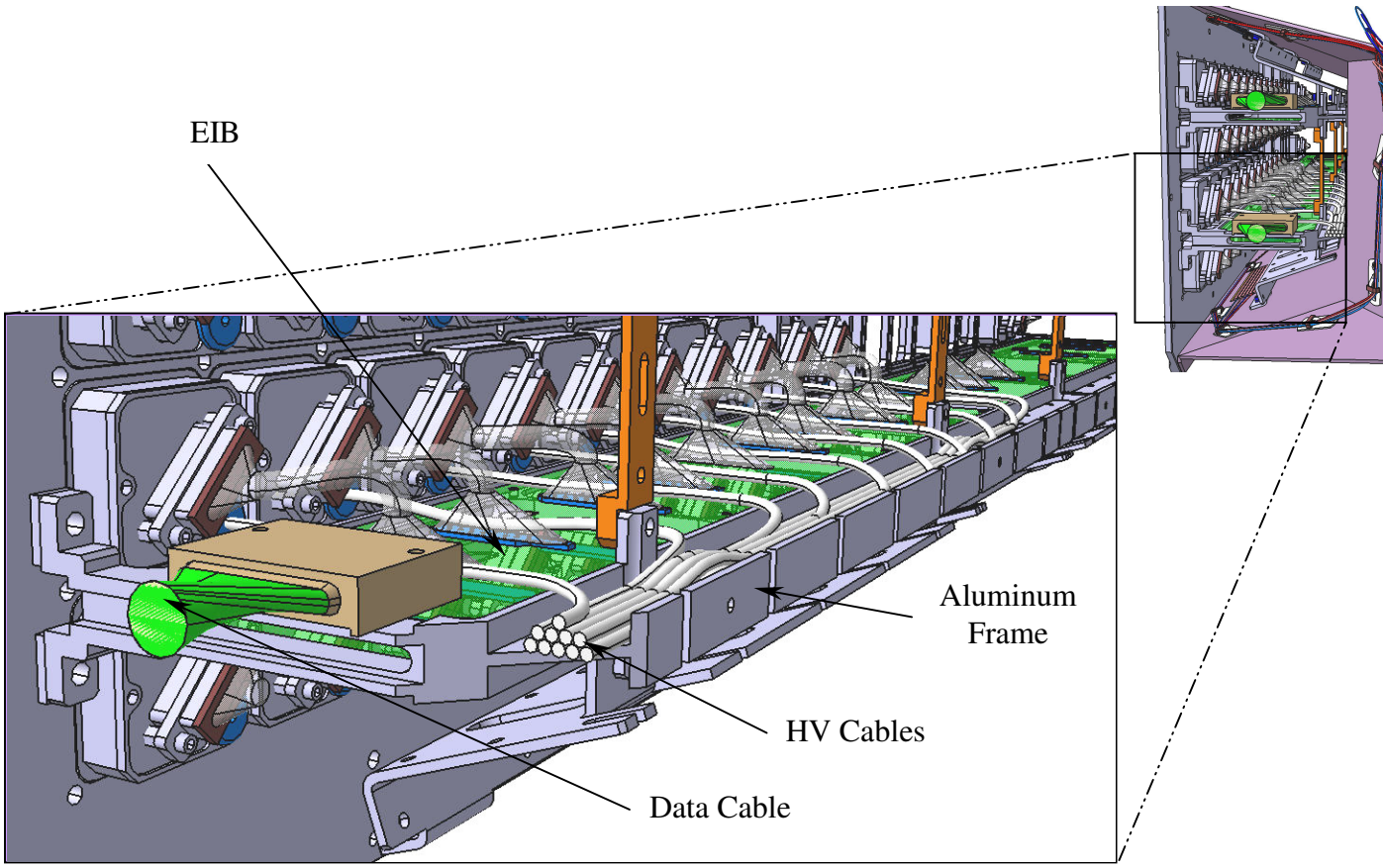

Figure 5.11-9 EIBs in their frames and mounted to the ECAL back panels

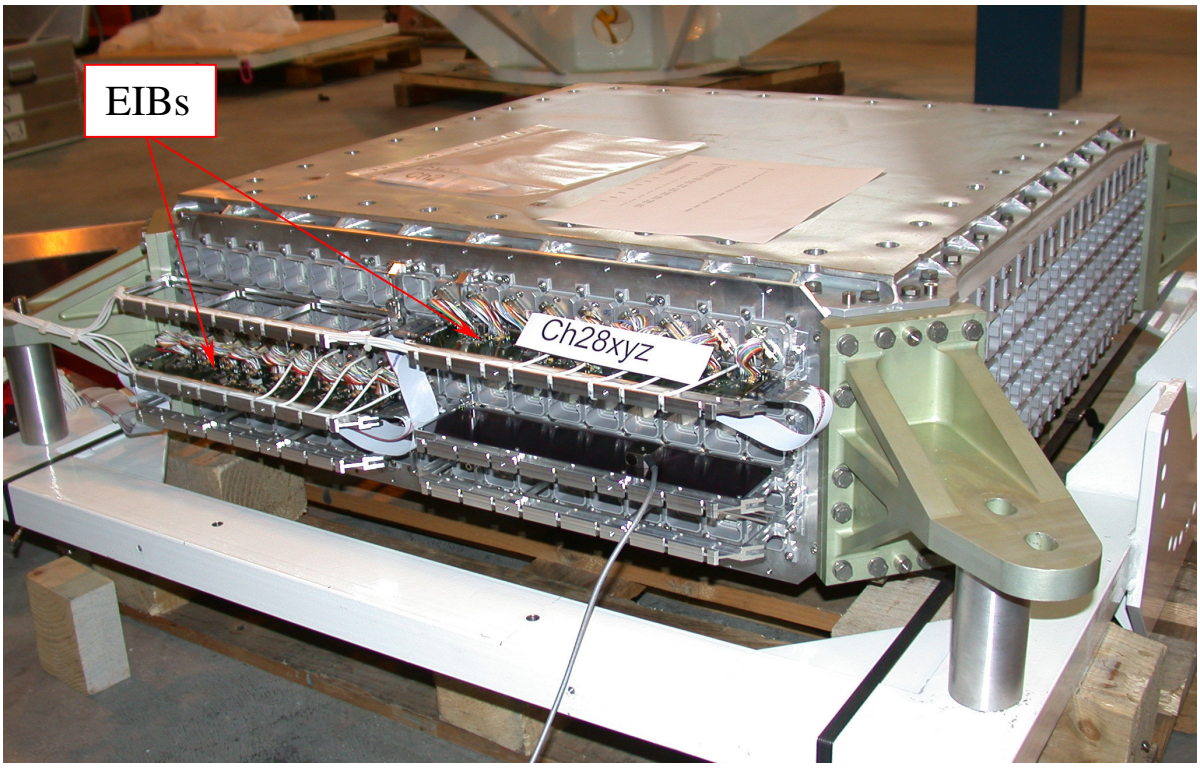

Figure 5.11-10 ECAL Engineering Model with some ECAL Intermediate Boards (EIBs) mounted in their frames

The ECAL utilizes two types of electronics boxes, the E-Crate and ECAL High Voltage (EHV) boxes, which are mounted to the lower USS-02 structure (Figure 5.11-11). The two E-Crates provide data acquisition and triggering functions and the four EHV boxes contain high voltage (HV) bricks (Figure 5.11-14) – each with 55 HV channels per brick –supply the high voltages for PMT operations. The HV bricks are fully potted. Two EHV boxes mounted on diagonally opposite legs of the lower USS-02 accommodate two HV bricks each, while the EHV boxes mounted on the two other legs accommodate one brick each. Three bricks are packaged per each of the four EHV boxes. The ECAL utilizes high voltages up to 800 VDC to operate the PMTs. Figure 5.11-15 provides a graphical representation of the HV design.

The cabling for HV, data and triggering are routed about the lower USS-02 using cable guides (Figures 5.11-11 through 5.11-13), the HV being routed separately from the data and trigger cabling. Figures 5.11-10 and 5.11-11 show the routing for data and trigger

cabling. Cable runs are carefully designed to keep the critical timing of recorded events synchronized.

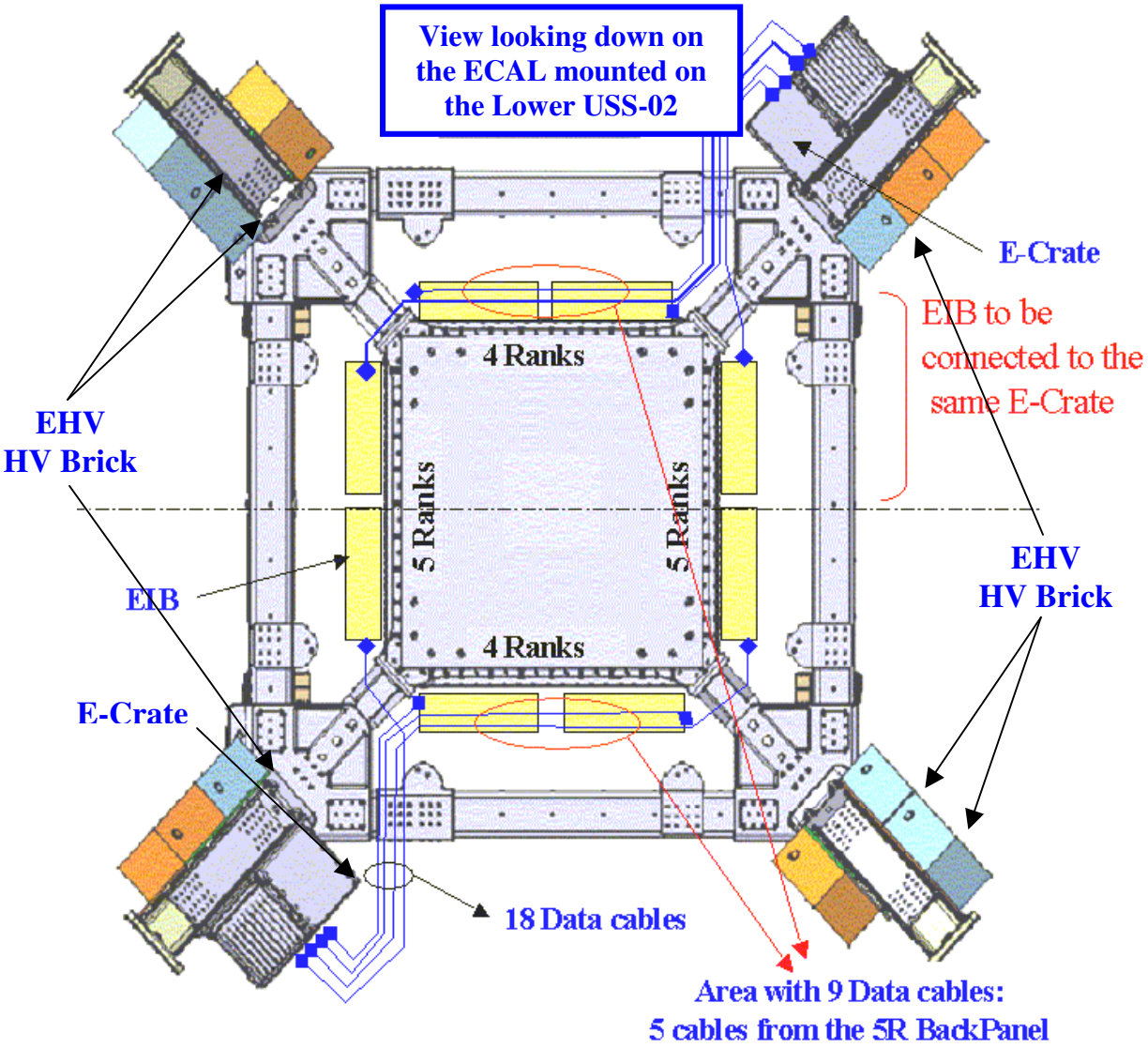

Figure 5.11-11 Location of E-Crates and EHV High Voltage Bricks / Routing of ECAL Data Cables

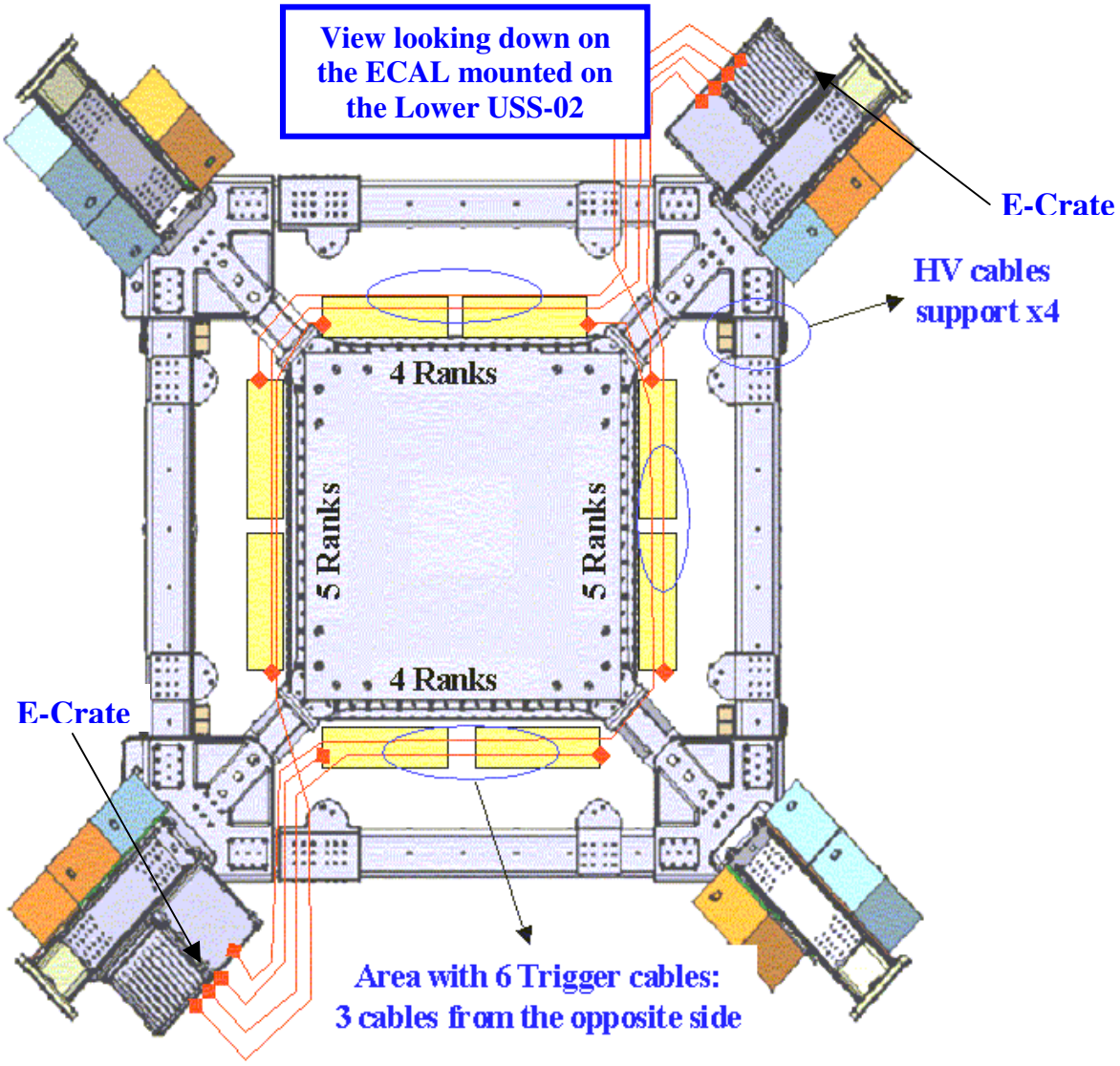

Figure 5.11-12 Routing of ECAL Trigger Cables

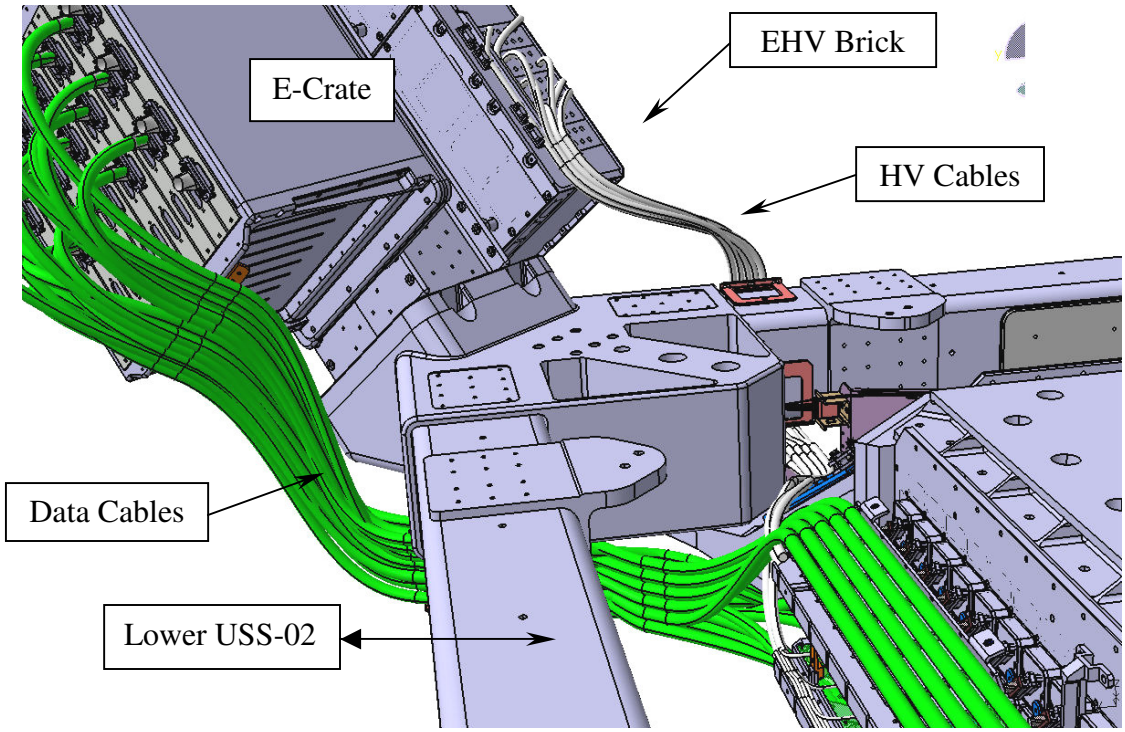

Figure 5.11-13 Routing of the HV and Data Cables from the ECAL to the HV Bricks and E-Crate

Figure 5.11-14 ECAL HV Brick

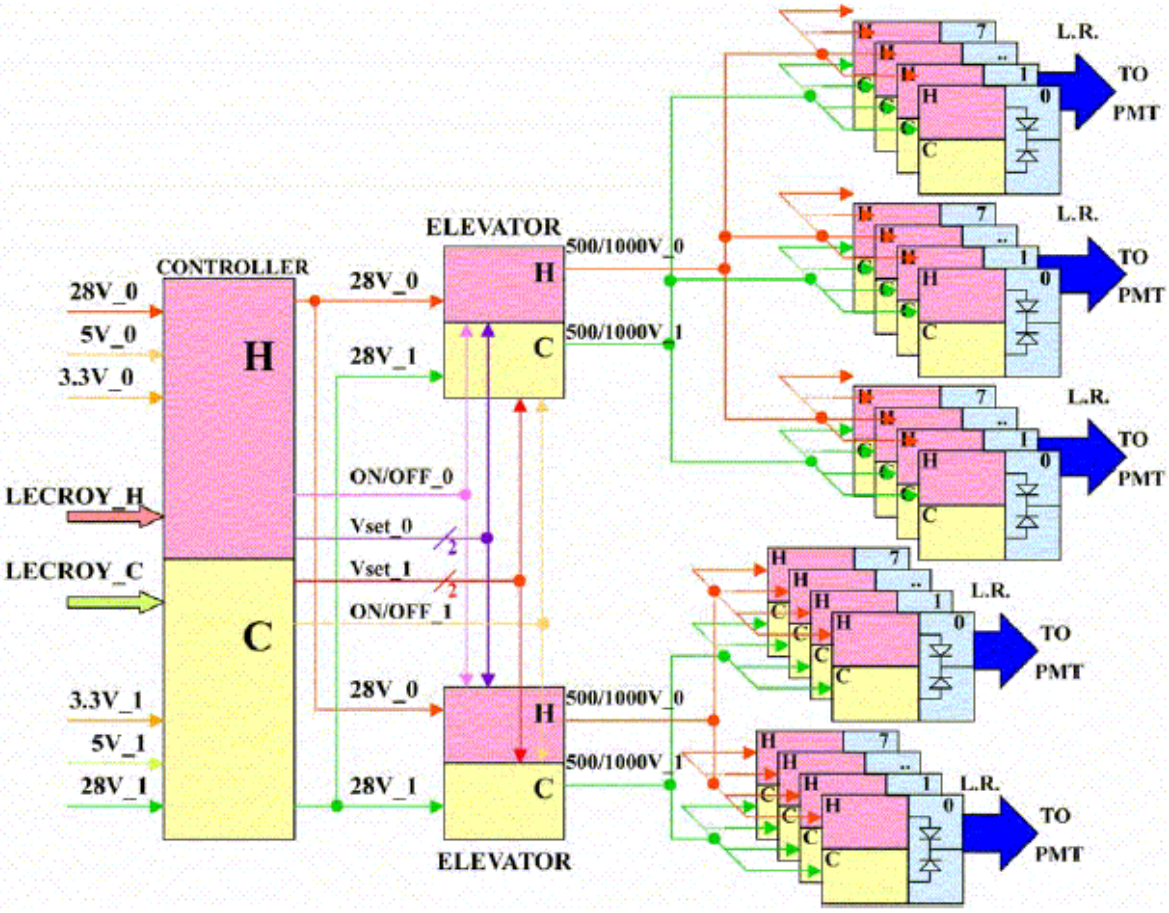

Figure 5.11-915 ECAL High Voltage Design